Development of Borehole GPR Techniques to Monitor Moisture Redistribution

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RESEARCH OBJECTIVES

Borehole Ground Penetrating Radar (GPR) tomography provides a high-resolution technique with which to characterize the temporal and spatial changes associated with fluid flow and moisture redistribution in the subsurface. Efforts are underway to streamline both the acquisition and processing of GPR data in order to provide real-time monitoring of a variety of changing fluid flow regimes.

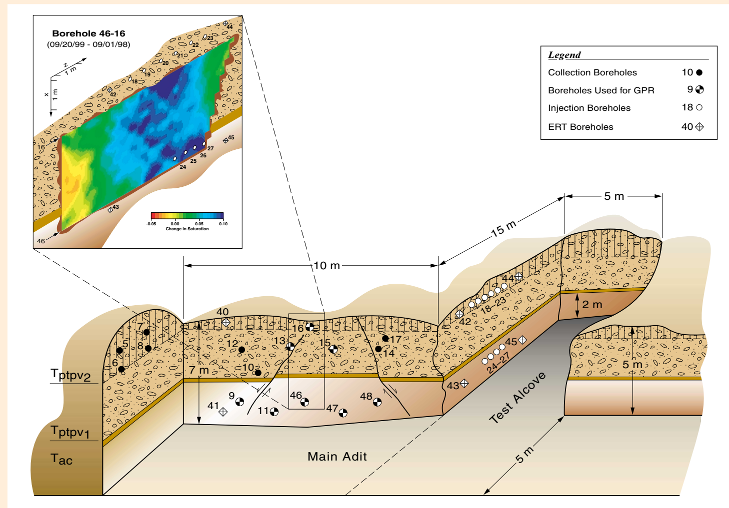

Figure 1. Borehole GPR tomogram acquired at the Busted Butte experimental site. The image illustrates the change in rock saturation between two boreholes as a result of tracer injection (dark blue colors represent increased saturation).

APPROACH

In the borehole GPR method, modified surface radar antennas are emplaced into a rock formation and high-frequency electromagnetic signals are transmitted through the formation to a receiving antenna. The dielectric permittivity of the rock has a strong influence on the propagation of the signal and whether it travels at a high or low velocity. Moisture content affects dielectric permittivity and hence has such an effect. The high dielectric permittivity (k) of water (k ~ 80) or wet rock (k ~ 20-30) in contrast to drier rock (k ~ 3-6) typically results in greatly reduced signal velocities. Because such changes in signal character are what are to be measured over the course of a radar study, any increase (or decrease) in background moisture content resulting from the fluid migration (or rock dry-out) should result in measurable changes in the received radar wave velocity. The transmitted signals may be represented as multiple ray paths crossing through a zone of interest in the subsurface. If sufficient ray paths are recorded, a tomographic image may be obtained through computer processing.

ACCOMPLISHMENTS

GPR tomography has been undertaken in support of a variety of experiments, including the controlled injection of a fluid tracer into the subsurface and the thermal activation of a rock mass and the accompanying moisture redistribution. Both experiments are ongoing and are conducted in support of the characterization of the potential high-level nuclear waste repository at Yucca Mountain, Nevada. The results of the GPR tomography indicate that the technique is sufficiently sensitive to detect extremely small changes in moisture content (<2-3%) related to both increasing and decreasing rock saturation over reasonably large distances (>10m). The technique has provided a means for delineating the extent of moisture redistribution and for highlighting specific fluid transport pathways. Such information has been used to verify hydrologic modeling undertaken in advance to predict fluid flow properties.

SIGNIFICANCE OF FINDINGS

Borehole GPR tomography provides a method with which to gather relatively high-resolution estimates of moisture content between two boreholes. The information obtained extends the zone of investigation beyond the traditional reach of most methods — that of the immediate region of the borehole. Information obtained on moisture redistribution and fluid flow between boreholes allows for data sampling not available through other means. The GPR tomography method provides an invaluable means for verifying the predictions made by hydrologic models. In this way, this technique appears to be quite successful in enhancing our understanding of fluid flow in the subsurface.

RELATED PUBLICATIONS

Y.W. Tsang, J. Apps, J.Birkholzer, J. Peterson, E. Sonnenthal, N. Spycher and K. Williams, Yucca Mountain drift scale test progress report, Berkeley Lab report LBNL-42538, 1999.

ACKNOWLEDGMENTS

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